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A COMPARISON OF THREE METHODS OF ARITHMETIC COMPUTATION BY THE BLIND

A Dissertation Submitted in Partial Fulfillment
of the Requirement for the Degree of
Doctor of Education

Gaylen Gerd Kapperman

College of Education

School of Special Education
and Rehabilitation

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G.G.K.

ABSTRACT

Kapperman, Gaylen G. "A Comparison of Three Methods of Arithmetic Computation by the Blind." Unpublished Doctor of Education dissertation, University of Northern Colorado, 1974.

Purpose

It has long been recognized by educators of the visually handicapped that their students find it very difficult to attain achievement levels in arithmetic computation equal to or greater than the standards set by their sighted counterparts. With regard to that fact, it was the purpose of this study to investigate the relative effectiveness of the three major methods of arithmetic computation by the blind (the Braillewriter, the Cranmer Abacus, and mental calculation). Effectiveness was defined in terms of accuracy and efficiency. Accuracy was defined as the total number of correct responses on each of three equivalent forms of an addition test. Efficiency was defined as the total number of correct responses divided by the total number of whole minutes required to complete each form of the test.

Procedures

The sample in this study consisted of 16 Braille students enrolled in the fifth through twelfth grades at the Kansas State School for the Visually Handicapped in Kansas City, Kansas.

A five-week treatment period was carried out during which time the subjects were instructed in the use of the Cranmer Abacus. Twenty-two fifty-minute instructional sessions were devoted to teaching the use of the abacus. The twenty-third, twenty-fourth, and twenty-fifth sessions were used for testing. Because of limited instructional time, only the procedures for adding with the abacus were taught. In their regular educational program, the subjects had learned to use the Braillewriter and mental calculation to compute arithmetic problems.

Multiple linear regression was used to analyze the results of the final tests. The effects of three extraneous variables--age, IQ, and individual differences among subjects--were statistically controlled.

Findings

It was stated in two null hypotheses that there were no statistically significant differences among methods with regard to accuracy and efficiency. Significant F values were found for both hypotheses leading to their

rejection. The Scheffe test for multiple comparisons was applied to determine which means were significantly greater than the others. Statistically significant differences with respect to accuracy were not found to exist between the Braillewriter and mental calculation or between mental calculation and the Cranmer Abacus. A statistically significant difference with respect to accuracy was found to exist between the Braillewriter (the highest ranking device) and the Cranmer Abacus (the lowest ranking device). Statistically significant differences with respect to efficiency were not found to exist between mental calculation and the Braillewriter or between the Braillewriter and the Cranmer Abacus. A statistically significant difference with respect to efficiency was found to exist between mental calculation (the highest ranking strategy) and the Cranmer Abacus (the lowest ranking device).

Conclusion

The Cranmer Abacus did not fare well in these comparisons. It ranked lowest on both indices of effectiveness (accuracy and efficiency). The experimenter speculates that given equal instructional time in all three methods, subjects using the Cranmer Abacus may very well achieve average accuracy and efficiency scores equal to or

greater than average accuracy and efficiency scores of subjects using the Braillewriter and mental calculation. That speculation is based on the fact that the practical differences among the three methods on both indices of effectiveness were not great. Those small practical differences occurred after only five weeks of instruction with the abacus as opposed to years of training and practice in the use of the Braillewriter and mental calculation.

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CHAPTER I

INTRODUCTION

Statement of the Problem

It has long been recognized by professionals in the area of education for the visually handicapped that blind children find it difficult to reach the standards set by their sighted counterparts in achievement in mathematics. As early as 1937, statements relating to difficulty in arithmetic achievement among blind students began appearing in the literature. During the 1935-36 school year, the first administration of the specially adapted Stanford Achievement Test battery took place in two eastern schools for the blind. In reporting the results of this initial administration, Hayes (1937) stated:

> In a seventh grade tested, for example, we find superior attainment in language usage and geography (class median being about two years above the norm), inferior attainment in physiology and hygiene and in arithmetic computation, and about normal attainment in the other tests (p. 89).

After the Stanford Achievement Test (SAT) had been used for three successive years in these two schools, Hayes (1938) reported:

> Grade for grade the blind children in these two schools tested nearly up to the standards for the seeing ... in all parts of the series except in arithmetical computation (p. 27).

In 1941, Hayes brought to light the results of the administration of the SAT in nine geographically widely dispersed schools for the blind. His graphic display indicated that the children in these schools averaged 20% below their sighted peers in arithmetic computation. Again in 1944, in reporting the results of the SAT battery given in an even broader segment of schools for the blind, he stated the following (Hayes, 1944):

> ... the curves of attainment for the thirteen schools which have sent reports to the writer follow very different patterns--one being best in reading, another in geography; one being best in language usage, another in physiology; while the poorest test is almost always that in arithmetic computation ... (p. 99).

Thus, it appears that early workers in the area were cognizant of the existence of a very difficult area of academic achievement by blind students.

In order to attempt to remedy the problem of poor performance in mathematics, educators turned to different methods of teaching arithmetic computation. Mental calculation was advocated by many. Cambridge (1948) succinctly stated the case as follows:

> Perhaps the most concise statement of our ultimate objective is that we must train the mind of the blind person to replace the pencil of the sighted one. This is absolutely essential since in adult life mechanical

> aids in solving problems will be almost always unavailable due to their awkwardness. It follows unavoidably that we must modify, and in some cases change completely our methods of teaching arithmetic computation (p. 74).

Apparently the mental calculation approach did not solve the problem as the reader will note in the following paragraphs.

In a modern survey of arithmetic achievement among blind students (Nolan & Ashcroft, 1959), it was found that:

> Approximately 75 per cent of each group falls below the expected achievement for that grade. Median retardation increasing upward through the grades until it reaches 1 year 1 month for eighth grade children. When chronological age is taken into account, retardation becomes more pronounced.(p. 92).

In comparing the outcome of their investigation with Hayes' 1941 survey, the authors state:

> These results, then, are substantially the same as those obtained earlier by Hayes, where he reported that children in grades 4-9 achieved approximately 20% below the sighted norms in arithmetic computation. Our group in grades 3, 4, 6, and 8 achieved approximately 16% below the sighted norms in this test (p. 92).

A more recent survey of arithmetic achievement (Brothers, 1972) was a replication of the Nolan and Ashcroft study. The results of that survey are summarized as follows:

> The results clearly indicate that the overall

> achievement of Braille students in arithmetic computation has not improved over the past decade. While the group in 1959 achieved approximately 15 percent below the sighted norm (Nolan & Ashcroft, 1959), those tested in 1970 were approximately 27 percent below the norm (p. 6).

In the most recent survey, Brothers (1973) estimated the level of arithmetic achievement of visually handicapped students in public school programs. His findings are as follows:

> The mean difference between actual achievement level and expected level for the combined groups was minus 4 months for grade 4, minus 5 months for grade 6, and minus 7 months for grade 8. ... In the present study the mean scores of braille students were approximately 8 percent below the expected achievement levels, and large type students averaged 9 percent below grade level (p. 576).

Thus, it appears that the problem of underachievement in arithmetic computation among blind students has been with us for many years.

With the advent of the Cranmer Abacus in the early 1960's, a new device appeared on the scene which holds great promise for enabling blind students to overcome their difficulties in arithmetic computation. This adaptation of the Japanese soroban was specially developed for use by the visually handicapped.

An eight-month pilot study (Nolan & Morris, 1964) was conducted in order to ascertain the feasibility of successfully instructing blind students in the use of the

Cranmer Abacus. Statistically significant improvement was found when pretest and posttest scores were compared. The investigators state that "the results of the study indicate that use of the soroban does enable braille readers to increase their accuracy and speed in arithmetic computation (p. 16)." A rigorous comparison of different methods of computation was not included in this study.

In order to determine which methods of arithmetic computation are used most frequently by visually handicapped students, a survey (Lewis, 1970b) of residential and public school programs for the visually handicapped was conducted. The investigator reports that "Tabulation of responses on means of computation in general use throughout the grades showed that the Braillewriter, Cranmer Abacus, and mental calculation are the most generally used (p. 71)." In an article previewing the above results, Lewis (1970a) concludes:

> From the diversity of apparatus for computation in use in schools having Braille students, it seems that there has not as yet been any definite choice made to establish one best means. Perhaps further study is needed (p. 61).

In his replication of the 1959 Nolan and Ashcroft study, Brothers (1972) attempted to ascertain which methods of computation resulted in the best achievement scores. Due to the lack of control of relevant variables, the researcher admitted that "The small and uneven

numbers of students using a particular device limited the application of statistical tests which would have demonstrated conclusively the superiority of a particular device (p. 4)."

Purpose of the Study

It was the purpose of this study to investigate the relative effectiveness of the three major methods of arithmetic computation by the blind--mental calculation, Braillewriter, and Cranmer Abacus. Effectiveness was defined in terms of accuracy and efficiency (correct responses/time).

Statement of Hypotheses

1. There is no statistically significant difference in accuracy of arithmetic computation when mental calculation, the Braillewriter, and the Cranmer Abacus are used to compute addition problems.

2. There is no statistically significant difference in efficiency of arithmetic computation when mental calculation, the Braillewriter, and the Cranmer Abacus are used to compute addition problems.

Limitations of the Study

The first limitation of this study was that addition was the only arithmetic operation to be investigated. Subtraction, multiplication, and division were not included.

Secondly, the effectiveness of only the three major methods of arithmetic computation by the blind--mental calculation, the use of the Braillewriter, and the use of the Cranmer Abacus--were compared. Other devices such as the Taylor Slate, the Texas Slate, and the Cubarithm were not included in the comparison.

The subjects of the investigation were Braille readers in one residential school. Braille users in other residential schools and resource and itinerant programs for the visually handicapped were not included. Visually handicapped students who use printed educational materials were also excluded from the study.

Braille students in grades five through twelve inclusive were included in the study. Students in grades four and below were excluded from the study.

The number of fifty-minute instructional sessions, during which the use of the abacus was taught, was limited to twenty-two.

The Hawthorne Effect has not been controlled. That is, exposure to a new and interesting device may have caused high motivation for learning which ordinarily would not operate in a nonexperimental situation. Also, no follow-up has been planned to determine if the effects of the treatment were permanent.

Definition of Terms

Braille students--severely visually limited students for whom Braille is the major means of reading educational material.

Cranmer Abacus--the Japanese soroban especially adapted for use by the blind; consists of thirteen rods, each holding four beads below the separation bar and one bead above the separation bar; with extended practice, addition, subtraction, multiplication, division, extraction of roots, and the calculation of trigonometric functions can be performed; manufactured by the American Printing House for the Blind.

Braillewriter--a device commonly used by the blind to produce Braille; consists of six keys, a space bar, a return lever, and a roller to facilitate the insertion and movement of paper.

accuracy--measure of effectiveness represented by the total number of correct responses for each subject.

efficiency--measure of effectiveness represented by a coefficient obtained by dividing the total number of correct responses by the total number of minutes required to complete the task.

CHAPTER II

REVIEW OF THE LITERATURE

Arithmetic Achievement of Blind Students

A study by Nolan and Ashcroft (1959) was the first well-documented investigation into the arithmetic achievement of blind students in recent times. In October, 1958, the researchers enlisted the aid of personnel in nine schools for the visually handicapped to administer a newly revised form of the Arithmetic Computation subtest of the Stanford Achievement Test battery. All four levels of the subtest were administered--Primary, Elementary, Intermediate, and Advanced. At each level, only one grade was chosen to receive the test. At the Primary Level, 77 children in grade three took the test. At the Elementary Level, 70 children in grade four responded to the test. At the Intermediate Level, 57 children in grade six were administered the test. At the Advanced Level, 78 children in grade eight were given the test. The data were sent to the American Printing House for the Blind, where they were tabulated. Results indicate that blind children do not achieve in arithmetic computation at levels comparable to

the achievement of their sighted peers. According to the authors, 75% of the children in each grade fell below the expected grade level. As the children progress through the grades, the retardation becomes more severe. Third grade children's median lag in achievement was 7 months. Median retardation for fourth grade children was 5 months. Sixth grade children were 1 year behind their sighted peers as reflected in the median score for that grade. Median retardation for eighth grade students was 1 year 1 month. The group as a whole achieved 16% below sighted norms.

Brothers (1972) replicated the Nolan and Ashcroft study in order to determine present levels of arithmetic achievement. Eight of the original schools and four additional ones participated in the survey. A total of 269 children were given the Arithmetic Computation subtest of the Stanford Achievement Test (52 third-graders, 76 fourth-graders, 60 sixth-graders, and 81 eighth-graders). Results indicated that 88% of the group fell below sighted norms. Again, retardation increases as children progress through the grades. The median lag in achievement for third grade children was 1 year 1 month. Median retardation for fourth grade children was also 1 year 1 month. One year 6 months represented the median retardation in achievement for sixth grade children. Eighth grade children registered the largest median lag in

achievement at 1 year 8 months. The subjects in this study averaged 27% below the norms for sighted students.

Brothers (1973) repeated the study in public school programs for the visually handicapped. He reports the following:

> A total of 263 students representing 42 school districts in 10 states were tested. The number represented approximately 24 percent of the braille readers and 9 percent of the large type students enrolled in the target grades of all public school programs in the country. A comparison of mean scores revealed no significant differences in achievement between braille and large type students at any grade level. The mean difference between actual achievement level and expected level for the combined groups was minus 4 months for grade 4, minus 5 months for grade 6, and minus 7 months for grade 8. Previous data have indicated that braille students in residential schools scored an average of 16 to 27 percent below the norm (Brothers, 1972; Nolan & Ashcroft, 1959). In the present study the mean scores of braille students were approximately 8 percent below the achievement levels, and large type students averaged 9 percent below grade level (p. 576).

<u>Computational Devices and Strategies</u>

Nolan and Morris (1964) conducted an eight-month study to determine what effect an instructional program in the use of the Cranmer Abacus might have upon blind students' facility in arithmetic computation. At the beginning of the treatment period, the Arithmetic Computation subtest of the Stanford Achievement Test battery and the more difficult Madden-Peak Arithmetic Computation Test were given to 42 blind students in the seventh, eighth, and ninth grades. The same tests were

administered four months later as well as at the end of the treatment period, eight months later.

Results indicated no statistically significant improvement in accuracy on the SAT from the first to the second testing, but statistically significant improvement was indicated from the first to the third testing. The results of the more difficult Madden-Peak indicated significant improvement over both the four- and the eight-month period. A mean reduction in time to complete the SAT of 3.32 minutes from the first to the third testing was statistically significant. Because almost no students completed the Madden-Peak on any testing, no analysis of data for speed of completion for that test was possible.

Two major shortcomings exist in this study. The same forms of the SAT and the Madden-Peak were used as the pre- and posttests. The use of the same examinations as pre- and posttests is a glaring weakness. Also, a rigorous comparison of methods of computation was not included in the investigation. Little mention was made of the computational devices used to compute the problems on pretests.

Lewis (1970b) surveyed residential and public school programs for the visually handicapped to discover which methods of arithmetic computation are most prevalent among blind students. Questionnaires were sent to all

residential schools in the United States and one in Canada. With 31 schools responding, a 70 percent return rate was realized. Resource rooms accounted for 43 responses.

The Braillewriter, the Cranmer Abacus, and use of mental calculation are the principal means of arithmetic computation in both residential and resource programs. Ninety percent of the residential schools reported the Braillewriter as a means of arithmetic computation. Use of the Cranmer Abacus as a computational tool was reported by 87 percent. Mental calculation was reported being used in 77 percent of the schools. Obviously, there is an overlap of computational methods. This fact indicates that a combination of the methods is used in residential schools.

Much the same situation exists in resource rooms. Replies from resource teachers indicate that 74 percent advocate use of the Braillewriter in arithmetic computation. These respondents also report that mental calculation is used to supplement the Braillewriter. Thirty-five percent of the public school respondents indicate that the Cranmer Abacus is used to calculate arithmetic problems. Again, an overlap exists suggesting that a combination of the tools is being used in these programs. It is apparent from the results of this survey that no one method has received overwhelming acceptance.

CHAPTER III

METHODS

Introduction

It was the purpose of this study to examine the effectiveness of three methods of arithmetic computation by the blind. Mental calculation, use of the Braillewriter, and use of the Cranmer Abacus were compared on two criteria--accuracy and efficiency--when addition problems were computed.

The sample in the study comprised 16 Braille readers who attended the Kansas State School for the Visually Handicapped in Kansas City, Kansas. The subjects were enrolled in the fifth through twelfth grades.

Because there were no standardized tests of arithmetic computation which were appropriate for evaluating the results of the experiment, the experimenter constructed three equivalent forms of the same addition test.

A counter-balanced schedule of test administration was devised in order to obviate contamination of results through practice effect because of order of test administration or order of methods used to compute addition

problems. Also, the counter-balanced schedule ensured that any disparity that may have existed among test forms would not bias the results.

Multiple linear regression was used to analyze the data resulting from the experiment. Through the use of the regression model, the variance of the criterion scores due to age, IQ, and individual differences among subjects was excluded from the analysis.

Subjects

The sample in this study was comprised of 16 students from the Kansas State School for the Visually Handicapped. The subjects were enrolled in the fifth through twelfth grades. The mean age of the group was 188 months (15 years, 8 months). Ages ranged from a low of 135 months (11 years, 3 months) to a high of 235 months (19 years, 7 months). The mean IQ of the group was 100.6 with a standard deviation of 15.9. IQ's ranged from a low of 57 to a high of 120 (see Appendix D for a full listing of ages and IQ's). Because of severe limitation of vision, each subject utilized Braille as his major means of reading educational material.

Students with educationally useful vision were not included in the study because the methods studied were not appropriate for that population. Braille students in resource and itinerant programs in the public schools were

also not included.

Treatment

The treatment in this study consisted of teaching the use of the Cranmer Abacus to blind students (see Appendix A for a detailed description of the design and operation of the Cranmer Abacus). Although all four arithmetic processes are possible with the use of an abacus, only instruction in addition was given.

With the abacus as a computational tool, the process of addition is a mechanistic one. Specific rules govern the addition of each of the nine digits. There are three ways to add each of the digits except five, for which there are only two ways. Direct addition is the simplest method of addition. This process entails moving the designated number of counters toward the separation bar. For example, to add one, one of the "earth counters" is moved up toward the separation bar. To add three, three of the "earth counters" are moved up toward the separation bar. To add five, the "heaven counter" is moved downward toward the separation bar. To add seven, two "earth counters" are moved upward toward the separation bar and the "heaven counter" is moved downward toward the separation bar.

In many cases, direct addition is impossible because an insufficient number of counters remains uncommitted to

the separation bar. In these cases, the specific rules, called "secrets," are brought into play. Each of the digits, one, two, three, four, six, seven, eight, and nine, has two rules governing its addition. Five has one rule. For example, to add one, set five and clear four, or clear nine and set one left. To add two indirectly, set five and clear three, or clear eight and set one left. To add five, which has only one rule, clear five and set one left. To add seven, set two, clear five, and set one left, or clear three and set one left. The rules continue in this fashion through nine (see Table 1 for a full listing of rules governing indirect addition).

Instructing students in the use of the abacus for purposes of addition can be divided into three major areas of concern. Learning to set numbers is the initial step. The next phase involves learning to add numbers directly. The final and by far most complex stage is learning to deal with the rules for adding numbers indirectly.

Instructional sessions were allocated to each of the three stages in quantity commensurate with the complexity of the stage. A five-week treatment period was carried out with twenty-two fifty-minute instructional sessions devoted to teaching the use of the abacus. The last three sessions were given over to testing. In all, twenty-five sessions were available for dealing with the abacus.

TABLE 1

LIST OF RULES FOR INDIRECT ADDITION

To Add	Rules
1	Set 5, Clear 4
1	Clear 9, Set 1 left
2	Set 5, Clear 3
2	Clear 8, Set 1 left
3	Set 5, Clear 2
3	Clear 7, Set 1 left
4	Set 5, Clear 1
4	Clear 6, Set 1 left
5	Clear 5, Set 1 left
6	Set 1, Clear 5, Set 1 left
6	Clear 4, Set 1 left
7	Set 2, Clear 5, Set 1 left
7	Clear 3, Set 1 left
8	Set 3, Clear 5, Set 1 left
8	Clear 2, Set 1 left
9	Set 4, Clear 5, Set 1 left
9	Clear 1, Set 1 left

A detailed description of the instructional plan follows (see Table 2). The schedule called for an introductory period in which the experimenter introduced the students to the abacus. At that time, newly purchased abacuses were given to the subjects. Subjects were told that the abacuses were theirs to keep. They were to practice with the new devices outside of instructional periods. After initial orientation, work began on learning to set numbers. The second session was also devoted to setting numbers. The third session was given over to instruction in direct addition. Beginning with the fourth session, instruction in the rules governing indirect addition of numbers occurred. The rules for adding one and two were introduced during the fourth session. During the fifth session, "secrets" for adding three and four were taught. The sixth session was devoted to practice and consolidation of previously learned skills. The seventh session was given over to instruction in the rules for adding five and six. Rules governing the addition of seven and eight were assigned to the eighth session. The ninth session was again devoted to practice and consolidation of previously learned skills. The tenth session comprised instruction in the indirect method for adding nine. The remaining twelve instructional sessions were given over to practice and consolidation of all previously

TABLE 2

SCHEDULE OF INSTRUCTION AND TESTING PERIODS

	Monday	Tuesday	Wednesday	Thursday	Friday
Week #1	Introduction and Orientation	Setting Numbers	Direct Addition	Secrets for Adding #1 and #2	Secrets for Adding #3 and #4
Week #2	Practice	Secrets for Adding #5 and #6	Secrets for Adding #7 and #8	Practice	Secrets for Adding #9
Week #3	Practice	Practice	Practice	Practice	Practice
Week #4	Practice	Practice	Practice	Practice	Practice
Week #5	Practice	Practice	Test Session #1	Test Session #2	Test Session #3

learned skills. The twenty-third, twenty-fourth, and twenty-fifth sessions were used for administering test instruments.

Many activities were used to motivate students. Initial emphasis was placed on developing accuracy. After sufficiently high levels of accuracy had been attained, the development of speed was the major focus of attention. Controlled drill with the experimenter leading the group was the mainstay of instructional activities. Students received immediate feedback on the accuracy of their answers in practice exercises. Periodically, students also took short examinations which were given in the same format as the final test instruments. Contests within groups to develop both speed and accuracy were held. A tape recorder was used to record series of numbers to be added. The tapes were played back twice to enable students to check their own answers. Students also took turns leading the group in drill activities.

It was considered unnecessary to provide instruction in the use of Braillewriters and mental calculation for purposes of arithmetic computation because the subjects had already learned those methods in their regular educational program (see Appendix B for verification of that fact).

Because of the relatively large number of students (16) who participated in the study, the sample was divided into two smaller groups. The 8 youngest subjects were assigned to one group and the remaining 8 oldest subjects were assigned to the other group. The experimenter considered it improper teaching tactics to attempt to instruct 16 blind students at the same time. Close supervision and monitoring of student activity were required. This could not be accomplished with 16 subjects in the same instructional period. Therefore, each day during the five-week treatment period included two equivalent instructional sessions. The 8 youngest subjects participated in the first session of the day while the 8 oldest subjects were included in the second instructional session. Exactly the same activities took place for each group. Only during the last three days of the treatment period, during which tests were administered, did all subjects participate together.

Along with the regular sessions each day, a third instructional period was arranged immediately after school. During this time, subjects who were absent from the regular sessions received special tutoring on work which they had missed.

Instrumentation

Three equivalent forms of a test of addition were required to assess the effectiveness of the three methods of arithmetic computation. Because no published, standardized tests of arithmetic computation existed which were appropriate to the task, the experimenter compiled the instruments.

Equivalency of forms was considered of utmost importance; therefore, careful attention was paid to this component in the construction of the tests. In choosing the problems for the twenty-three-item instruments, the following six criteria were followed scrupulously:

1. The items should be ordered from easy to difficult.
2. The corresponding items at each difficulty level must have the same arithmetic processes operating for the solution of the problems. For example, the items should progress in the following manner: (a) no regrouping, (b) regrouping units column only, (c) regrouping tens column only, (d) regrouping units and tens columns, (e) regrouping units, tens, and hundreds columns, (f) regrouping units, tens, hundreds, and thousands columns.
3. Each corresponding addend must contain the same number of digits.
4. The same number of addends must comprise each of the corresponding items at each difficulty level.
5. The corresponding sums must contain the same number of digits.
6. The corresponding sums must approximate each other in magnitude without being equal.

After three items at each of the twenty-three difficulty levels had been selected following the criteria listed above, they were randomly assigned to tests A, B, and C. The random assignment was accomplished through the use of a newly purchased die. Test A was assigned numbers one and two on the die. Test B was assigned numbers three and four on the die. Test C was assigned numbers five and six. The random assignment was carried out as follows:

> The first item in a difficulty level was chosen for assignment. The die was rolled. The item was then assigned on the basis of the number which showed on the die. The second item in that difficulty level was chosen. The die was again rolled. The item was assigned to the appropriate test on the basis of the number which showed on the die. The third item's assignment was then determined and it was placed in the remaining test.

This procedure was designed to obviate any systematic bias which may have operated during the construction of the three forms. If a systematic bias did exist before the randomization procedure was carried out, after the process was completed, that bias would be randomly distributed throughout the three forms and no longer operative. This procedure was designed to ensure equivalency of forms (see Appendix C for copies of the test instruments).

Horizontal addition was chosen as the format of the three forms for two specific reasons. The horizontal

format rather than the traditional vertical layout of addition problems ensured that the subjects had to use their designated methods of computation. If the vertical layout had been used, no guarantee would have existed that the subjects had used their Braillewriters to recopy the problems or that the subjects had actually used the Cranmer Abacus to calculate the solutions. In the vertical format, it would have been very easy for the subjects to add down the columns and write the answers without the aid of any particular device. In the horizontal layout, the subjects first had to recopy the problems with the Braillewriter before addition began. When the abacus was used, the subjects had to transfer each addend to the abacus as they performed the addition.

The second reason for choosing horizontal addition was that this format most nearly simulates the presentation of addition problems in everyday life. In day-to-day living, data do not come to us neatly stacked one on top of another, but rather are presented to us in a form which requires some effort to organize on our part.

The test was transformed into Braille by the experimenter and duplicated on plastic Braillon through use of the Thermoform. The test in Appendix C is the print copy of the Brailled form. Of course, the answers, as shown in Appendix C, did not appear on the Brailled copies.

Administration of Tests

A counter-balanced test schedule with subjects assigned randomly to test groups was devised (see Table 3). First, subjects were randomly assigned to three groups. Each group was systematically distributed over methods of computation (see Table 4). The groups were then assigned a form of the test and a method of computation for the first day's administration. The members of each group were randomly assigned to two smaller groups by tossing a coin. The six subgroups were assigned appropriate test forms and methods of calculation. The forms and methods were varied from the second to the third administration. Upon receipt of the list of names of the participants in the study, the experimenter assigned subjects alphabetically to numbers one through sixteen.

This design has many advantages. Among them, the following are of utmost importance:

1. All possible orders of test forms are distributed over test sessions.
2. All possible orders of methods are distributed over test sessions.
3. Test forms are evenly distributed over methods.
4. Random assignment of subjects to all possible orders of test forms and all possible orders of methods took place.

The counter-balanced test schedule was formulated to prevent the undesirable effects of several extraneous variables from contaminating the results. First of all,

TABLE 3

TEST SCHEDULE

Day #1	Day #2	Day #3
Braillewriter Group #1 Subject # 6, 7, 8, 10, 11 Test A	Mental Calculation Subject # 10, 11 Test C	Cranmer Abacus Subject # 10, 11 Test B
	Cranmer Abacus Subject # 6, 7, 8 Test B	Mental Calculation Subject # 6, 7, 8 Test C
Cranmer Abacus Group #2 Subject # 1, 3, 4, 5, 12, 14 Test C	Braillewriter Subject # 1, 3, 12 Test B	Mental Calculation Subject # 1, 3, 12 Test A
	Mental Calculation Subject # 4, 5, 14 Test A	Braillewriter Subject # 4, 5, 14 Test B
Mental Calculation Group #3 Subject # 2, 9, 13, 15, 16 Test B	Cranmer Abacus Subject # 9, 15, 16 Test A	Braillewriter Subject # 9, 15, 16 Test C
	Braillewriter Subject # 2, 13 Test C	Cranmer Abacus Subject # 2, 13 Test A

TABLE 4

ASSIGNMENT OF TEST GROUPS
TO
METHODS OF COMPUTATION

Braillewriter	Cranmer Abacus	Mental Calculation
Group #1 Test A Subject # 1, 2, 5, 10, 11	Group #3 Test A Subject # 7, 8, 9, 12, 13, 14	Group #2 Test A Subject # 3, 4, 6, 15, 16
Group #2 Test C Subject # 3, 4, 6, 15, 16	Group #1 Test C Subject # 1, 2, 5, 10, 11	Group #3 Test C Subject # 7, 8, 9, 12, 13, 14
Group #3 Test B Subject # 7, 8, 9, 12, 13, 14	Group #2 Test B Subject # 3, 4, 6, 15, 16	Group #1 Test B Subject # 1, 2, 5, 10, 11

practice effect, due to the order of test forms or the order of methods, was controlled by this design (see Tables 5 and 6). The random assignment of subjects to test groups ensured that any potential bias due to subject/test interaction did not exist. Any potentially biasing effect of incongruence of test forms was controlled by evenly distributing test forms over methods and test sessions. Random assignment of subjects to test groups resulted in random assignment of subjects to method/form/test session categories. Thus, any adverse effect from that interaction was controlled.

The data for measuring speed was gathered during the three test sessions. No time limit was set for the completion of the tests, but rather the time required by each subject to finish his test was noted in whole minutes.

An attempt to standardize testing conditions was made. All subjects took their assigned form of the test using the designated method during the same testing session. Each subject was given one Braillewriter and the necessary paper to record his answers. Those subjects who had been assigned Braillewriters as computational tools were given two Braillewriters--one for recording answers and one for computation. Those subjects who used either mental calculation or the Cranmer Abacus were

TABLE 5

ORDER OF TEST FORM ADMINISTRATION
FOR
EACH SUBJECT

Subject	Day #1	Day #2	Day #3
1	C	B	A
2	B	C	A
3	C	B	A
4	C	A	B
5	C	A	B
6	A	B	C
7	A	B	C
8	A	B	C
9	B	A	C
10	A	C	B
11	A	C	B
12	C	B	A
13	B	C	A
14	C	A	B
15	B	A	C
16	B	A	C

TABLE 6

ORDER OF ADMINISTRATION
OF
METHODS OF COMPUTATION
FOR
EACH SUBJECT

Subject	Day #1	Day #2	Day #3
1	Aba[a]	Brl[b]	MtC[c]
2	MtC	Brl	Aba
3	Aba	Brl	MtC
4	Aba	MtC	Brl
5	Aba	MtC	Brl
6	Brl	Aba	MtC
7	Brl	Aba	MtC
8	Brl	Aba	MtC
9	MtC	Aba	Brl
10	Brl	MtC	Aba
11	Brl	MtC	Aba
12	Aba	Brl	MtC
13	MtC	Brl	Aba
14	Aba	MtC	Brl
15	MtC	Aba	Brl
16	MtC	Aba	Brl

[a]Aba = Cranmer Abacus

[b]Brl = Braillewriter

[c]MtC = Mental Calculation

given one Braillewriter to record answers and were instructed not to use that device for computation.

The instructions to the subjects before beginning each test session were as follows:

> Put your paper in your Braillewriter. Write your name in the upper left hand corner of your paper. As you take the test, number your paper from one to twenty-three. Do the best job possible. Try to be as accurate as you can, but also go as fast as you can. When you are finished with the test, raise your hand and I will come to your desk and pick up your test paper. Then you are free to leave the room as quietly as you can. Do not begin until I tell you. Are there any questions? You may begin the test now.

Data Analysis

Multiple linear regression was used to analyze the data. Three forms of data were gathered. An index of accuracy in the form of the total number of correct responses was noted for each subject. An index of speed in the form of total minutes required to complete each form of the test was noted for each subject. An index of efficiency was calculated for each subject by dividing his total number of correct responses by the total number of minutes required for the completion of each form of the test.

The effects of three important concomitant variables were controlled statistically. First, because a repeated measures design was used, the contribution to the variance

of the criterion variable attributable to individual differences among subjects was controlled through the use of subject vectors. Secondly, an age vector was incorporated in the model to control for the effects of that variable. Lastly, a vector comprising IQ scores for each subject was included to control for that variable.

In assessing the effectiveness of the three methods of computation on the criterion of accuracy, the following full model was used:

$$Y_1' = a_0U+a_1X_1+a_2X_2+a_3X_3+a_4X_4+a_5X_5+a_6S_1+a_7S_2+ a_8S_3+a_9S_4+a_{10}S_5+a_{11}S_6+a_{12}S_7+a_{13}S_8+a_{14}S_9+ a_{15}S_{10}+a_{16}S_{11}+a_{17}S_{12}+a_{18}S_{13}+a_{19}S_{14}+a_{20}S_{15}+ a_{21}S_{16}$$

where:

Y_1' = total number of correct responses for each subject (accuracy scores).

U = unit vector.

X_1 = 1 if the score on the criterion was made by a subject using the Cranmer Abacus; 0 otherwise.

X_2 = 1 if the score on the criterion was made by a subject using the Braillewriter; 0 otherwise.

X_3 = 1 if the score on the criterion was made by a subject using mental calculation; 0 otherwise.

X_4 = age in months of each subject.

X_5 = IQ score for each subject.

S_1 = 1 if the score on the criterion was made by subject #1; 0 otherwise.

S_2 = 1 if the score on the criterion was made by subject #2; 0 otherwise.

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S_{15} = 1 if the score on the criterion was made by subject #15; 0 otherwise.

S_{16} = 1 if the score on the criterion was made by subject #16; 0 otherwise.

The above full model was compared to the following restricted model:

$$Y_1' = a_0U+a_4X_4+a_5X_5+a_6S_1+a_7S_2+a_8S_3+a_9S_4+a_{10}S_5+ a_{11}S_6+a_{12}S_7+a_{13}S_8+a_{14}S_9+a_{15}S_{10}+a_{16}S_{11}+ a_{17}S_{12}+a_{18}S_{13}+a_{19}S_{14}+a_{20}S_{15}+a_{21}S_{16}$$

The statistical hypotheses for this comparison were the following:

$$H_0: a_1 = a_2 = a_3$$
$$H_A: a_1 \neq a_2 \neq a_3$$

The alpha level was set at $p < .05$. The F test was used to determine the level of significance.

In assessing the effectiveness of the three methods of computation with regard to efficiency, the following full model was used:

$$Y_2' = a_0U+a_1X_1+a_2X_2+a_3X_3+a_4X_4+a_5X_5+a_6S_1+a_7S_2+ a_8S_3+a_9S_4+a_{10}S_5+a_{11}S_6+a_{12}S_7+a_{13}S_8+a_{14}S_9+ a_{15}S_{10}+a_{16}S_{11}+a_{17}S_{12}+a_{18}S_{13}+a_{19}S_{14}+a_{20}S_{15}+ a_{21}S_{16}$$

where:

Y_2' = efficiency scores for each subject (number of correct responses divided by the number of minutes required to complete the task).

U = unit vector.

X_1 = 1 if the score on the criterion was made by a subject using the Cranmer Abacus; 0 otherwise.

X_2 = 1 if the score on the criterion was made by a subject using the Braillewriter; 0 otherwise.

X_3 = 1 if the score on the criterion was made by a subject using mental calculation; 0 otherwise.

X_4 = age in months of each subject.

X_5 = IQ score for each subject.

S_1 = 1 if the score on the criterion was made by subject #1; 0 otherwise.

S_2 = 1 if the score on the criterion was made by subject #2; 0 otherwise.

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S_{15} = 1 if the score on the criterion was made by subject #15; 0 otherwise.

S_{16} = 1 if the score on the criterion was made by subject #16; 0 otherwise.

The above full model was compared to the following restricted model:

$$Y_2' = a_0U+a_4X_4+a_5X_5+a_6S_1+a_7S_2+a_8S_3+a_9S_4+a_{10}S_5+ a_{11}S_6+a_{12}S_7+a_{13}S_8+a_{14}S_9+a_{15}S_{10}+a_{16}S_{11}+ a_{17}S_{12}+a_{18}S_{13}+a_{19}S_{14}+a_{20}S_{15}+a_{21}S_{16}$$

The statistical hypotheses for this comparison were as follows:

$$H_0: a_1 = a_2 = a_3$$

$$H_A: a_1 \neq a_2 \neq a_3$$

The alpha level was set at $p < .05$. The F test was used to determine the level of significance.

When the null hypotheses were rejected, the Scheffé test for multiple comparisons was used to determine which means were significantly greater than the others.

The procedures outlined in this section are recommended for the repeated measures design by Kelly, Beggs, and McNeil (1969).

CHAPTER IV

ANALYSIS OF DATA

Introduction

A comparison of the three major methods of arithmetic computation by blind students--the Braillewriter, the Cranmer Abacus, and mental calculation--was carried out. The three methods were compared on two indices of effectiveness--accuracy and efficiency. Sixteen Braille students in grades five through twelve, enrolled at the Kansas State School for the Visually Handicapped, served as subjects in the experiment. At the conclusion of the five-week treatment period, during which time the subjects were taught to add using the Cranmer Abacus, three equivalent forms of the same addition test were administered. The results of the experiment were analyzed via multiple linear regression techniques. Three extraneous variables--age, IQ, and individual differences--were statistically controlled.

Hypothesis I

The following hypothesis was rejected at the .05 level of significance:

> There is no statistically significant difference in accuracy of arithmetic computation when mental calculation, the Braillewriter, and the Cranmer Abacus are used to compute addition problems.

The full model yielded an R^2 of .5980. The restricted model yielded an R^2 of .4870. The difference between the two figures, a drop of .1110, resulted in an F value of 3.87. That F value is significant at the .03 level (see Table 7).

TABLE 7

ANALYSIS OF DIFFERENCES AMONG METHODS WITH RESPECT TO ACCURACY

Model	R^2	ESS	
Full	.5980	330.72	
Restricted	.4870	422.03	
			F = 3.87
			P = .0321

$df_1 = 2$

$df_2 = 28$

The Scheffé test for multiple comparisons was employed to determine which means were significantly greater than the others. The mean accuracy score for the Braillewriter was significantly greater than the mean accuracy score for the Cranmer Abacus. Other significant comparisons were not discovered (see Table 8).

TABLE 8

COMPARISON OF MEAN ACCURACY SCORES

Method	Mean	Scheffé Comparisons F			Scheffé Comparisons F'
Brl[a]	18.06	Brl-MtC	2.19	(NS)	
MtC[b]	16.25	MtC-Aba	1.64	(NS)	
Aba[c]	14.69	Brl-Aba	7.62*		
					6.42

*P < .05

[a]Braillewriter

[b]Mental Calculation

[c]Cranmer Abacus

The standard weights, the beta weights, and the correlations between the individual predictors and the criterion scores (accuracy) are reported in Table 9.

TABLE 9

WEIGHTS AND CORRELATIONS ASSOCIATED WITH THE FULL MODEL FOR ACCURACY

	Variables	Standard Weights	Beta Weights	Correlations
	Aba[a]	.0052	.0457	-.2811
	Brl[b]	.3794	3.3320	.2953
	MtC[c]	.1735	1.5239	-.0142
	IQ	.2218	.0578	.0709
	Age	.0000	.0000	.0792
Subjects	1	.2491	4.2609	-.1663
	2	.2862	-4.8940	-.1455
	3	.3306	-5.6534	-.2287
	4	.0169	- .2894	.1247
	5	.0211	- .3613	-.0832
	6	.1390	2.3769	-.1039
	7	.1678	-2.8691	-.0832
	8	.0759	1.2974	.2079
	9	.1259	-2.1540	.0000
	10	.0384	.6574	.2079
	11	.0262	.4480	.1247
	12	.0341	- .5840	.1039
	13	.0885	1.5136	.1247
	14	.0301	.5156	.0624
	15	.4975	-8.5078	-.4158
	16	.1527	2.6113	.2703
	U		10.4738	

[a]Cranmer Abacus

[b]Braillewriter

[c]Mental Calculation

Hypothesis II

The following hypothesis was rejected at the .05 level of significance:

> There is no statistically significant difference in efficiency of arithmetic computation when mental calculation, the Braillewriter, and the Cranmer Abacus are used to compute addition problems.

The full model yielded an R^2 of .7691. The restricted model yielded an R^2 of .6804. The difference between the two figures, a drop of .0886, resulted in an F value of 5.37. That F value is significant at the .01 level (see Table 10).

TABLE 10

ANALYSIS OF DIFFERENCES AMONG METHODS WITH RESPECT TO EFFICIENCY

Model	R^2	ESS	
Full	.7691	1.07	
Restricted	.6804	1.48	
			F = 5.37
			P = .0106

$df_1 = 2$

$df_2 = 28$

The Scheffé test for multiple comparisons was employed to determine which means were significantly greater than the others. The mean efficiency score for mental calculation was significantly greater than the mean efficiency score for the Cranmer Abacus. Other significant comparisons were not discovered (see Table 11).

TABLE 11

COMPARISON OF MEAN
EFFICIENCY SCORES

Method	Mean	Scheffé Comparisons		
		F		F'
MtC[a]	.6698	MtC-Brl	5.98 (NS)	
Brl[b]	.5003	Brl-Aba	.5740 (NS)	
Aba[c]	.4478	MtC-Aba	10.26*	
				6.42

*P < .05

[a]Mental Calculation

[b]Braillewriter

[c]Cranmer Abacus

The standard weights, the beta weights, and the correlations between the individual predictors and the criterion scores (efficiency) are reported in Table 12.

TABLE 12

WEIGHTS AND CORRELATIONS
ASSOCIATED WITH THE FULL MODEL FOR EFFICIENCY

	Variables	Standard Weights	Beta Weights	Correlations
	Aba[a]	.0810	.0535	-.2212
	Brl[b]	.0230	.0152	-.0620
	MtC[c]	.2570	.1696	.2832
	IQ	.0119	.0002	.2052
	Age	.0000	.0000	.0713
Subjects	1	.0000	.0000	-.0233
	2	.1899	.2441	-.2226
	3	.0063	.0081	-.0150
	4	-.0307	-.0395	-.0565
	5	.2197	-.2823	-.2668
	6	.1227	.1576	-.1562
	7	.2976	.3824	.2921
	8	.1769	.2274	.1676
	9	.1477	.1898	-.1783
	10	.1235	.1587	.1122
	11	.1554	.1997	.1427
	12	.1138	.1462	.0984
	13	.0865	.1112	-.1174
	14	.0550	.0707	.0348
	15	.2852	.3664	-.3277
	16	.5036	.6471	.5162
	U		.4496	

[a]Cranmer Abacus

[b]Braillewriter

[c]Mental Calculation

Correlation Matrix

The correlation matrix representing the relationship of every variable with every other variable is reported in Table 13.

TABLE 13

CORRELATION MATRIX

		Acc	Spd	Eff	Aba	Brl	MtC	IQ	Age	Subjects 1	2	3	4	5
	Acc	1.00												
	Spd	.23	1.00											
	Eff	.56	.80	1.00										
	Aba	-.28	.04	.22	1.00									
	Brl	.30	.18	.06	.50	1.00								
	MtC	.01	.14	.28	-.50	-.50	1.00							
	IQ	.07	.34	.21	.00	.00	.00	1.00						
	Age	.08	.05	.07	.00	.00	.00	-.57	1.00					
Subjects	1	.17	.11	.02	.00	.00	.00	.01	.33	1.00				
	2	.15	.18	.22	.00	.00	.00	.28	-.05	-.07	1.00			
	3	.23	.16	.02	.00	.00	.00	.12	-.31	-.07	-.07	1.00		
	4	.12	.02	.06	.00	.00	.00	.20	-.40	-.07	-.07	.07	1.00	
	5	.08	.44	.27	.00	.00	.00	-.71	.35	-.07	-.07	-.07	.07	1.00
	6	.10	.11	.16	.00	.00	.00	.24	.33	-.07	-.07	-.07	.07	.07
	7	.08	.29	.29	.00	.00	.00	-.01	.09	-.07	-.07	-.07	.07	-.07
	8	.21	.15	.17	.00	.00	.00	.14	.35	-.07	-.07	-.07	.07	-.07
	9	.00	.17	.18	.00	.00	.00	.17	-.06	-.07	-.07	.07	.07	-.07
	10	.21	.13	.11	.00	.00	.00	.31	-.24	-.07	-.07	-.07	.07	.07
	11	.12	.14	.14	.00	.00	.00	.01	-.13	-.07	-.07	.07	.07	.07
	12	.10	.14	.10	.00	.00	.00	.18	-.27	-.07	-.07	-.07	-.07	-.07
	13	.12	.18	.12	.00	.00	.00	-.30	.23	-.07	-.07	-.07	.07	-.07
	14	.06	.11	.03	.00	.00	.00	-.30	-.08	-.07	-.07	-.07	-.07	-.07
	15	.42	.41	.33	.00	.00	.00	.09	-.32	-.07	-.07	-.07	.07	-.07
	16	.27	.29	.52	.00	.00	.00	.05	.18	-.07	-.07	-.07	.07	-.07

TABLE 13 (continued)

CORRELATION MATRIX

	Subjects										
	6	7	8	9	10	11	12	13	14	15	16
Acc											
Spd											
Eff											
Aba											
Brl											
MtC											
IQ											
Age											
Subjects 1											
2											
3											
4											
5											
6	1.00										
7	-.07	1.00									
8	-.07	-.07	1.00								
9	-.07	-.07	-.07	1.00							
10	-.07	.07	-.07	-.07	1.00						
11	-.07	-.07	-.07	-.07	-.07	1.00					
12	-.07	-.07	-.07	-.07	-.07	-.07	1.00				
13	-.07	-.07	-.07	-.07	-.07	-.07	-.07	1.00			
14	-.07	-.07	-.07	-.07	-.07	-.07	-.07	.07	1.00		
15	-.07	-.07	-.07	-.07	-.07	-.07	-.07	.07	.07	1.00	
16	-.07	-.07	-.07	-.07	-.07	-.07	-.07	-.07	.07	-.07	1.00

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

Discussion

Both hypotheses were rejected. Statistically significant differences were found among the three methods of arithmetic computation with respect to both accuracy and efficiency. In the case of Hypothesis I (accuracy), the Braillewriter was found to be statistically more accurate than the Cranmer Abacus. A statistically significant difference in accuracy was not found to exist between the Braillewriter and mental calculation or between mental calculation and the Cranmer Abacus. In the case of Hypothesis II (efficiency), mental calculation was found to be statistically superior to the Cranmer Abacus in efficiency. A statistically significant difference was not found to exist between mental calculation and the Braillewriter or between the Braillewriter and the Cranmer Abacus with respect to efficiency.

It is the writer's contention that even though statistical difference was found to exist among the three

methods, for practical purposes, those differences are of minor consequence. In fact, the differences, viewed in the light of practicality, favor the Cranmer Abacus, although it ranked lowest on both measures of effectiveness. After only five weeks of training with the abacus, subjects attained an average accuracy score of 14.69. This score is contrasted with 18.06, the average accuracy score achieved by subjects using the Braillewriter, the highest ranking device. A difference of only 3.37 is small, especially when one notes that the subjects had years of training and practice with the Braillewriter as opposed to a relatively brief period of instruction in the use of the Cranmer Abacus. Given that the subjects had equal opportunity to learn to use both devices, one might ask, how well would the Cranmer Abacus fare when placed in competition with the Braillewriter?

The same question can be posed with regard to efficiency. Subjects using the Cranmer Abacus, the lowest ranking device, averaged .4478. When using the highest ranking strategy, mental calculation, subjects made an average efficiency score of .6698. A difference of .2220 again is of little concern for practical purposes. How would the abacus have fared if the subjects had had equal training in both the abacus and mental calculation? The question remains an open one. Given equal training and

practice in all three methods, it is this writer's speculation that subjects using the Cranmer Abacus would achieve average scores equaling or exceeding the average scores for the Braillewriter and mental calculation.

In this study, age and IQ appear to have little relationship with accuracy and efficiency as reflected in the correlations between those two sets of variables (see Table 13). Age correlated .08 with accuracy and .07 with efficiency. IQ correlated .07 with accuracy and .21 with efficiency. All those correlations are very low. It may well be that other factors, such as motivation, had a much larger influence upon the variance of criterion scores than did IQ and age.

During the course of the treatment period, it became apparent to the experimenter that several subjects were experiencing difficulty in learning to manipulate the small beads of the abacus. It appeared that this lack of facility with the abacus was caused by a deficit in finger dexterity. That lack of facility was the source of much distress among those few subjects. One was never able to overcome his difficulty, although, in the judgment of the experimenter, he possessed sufficient intellectual power to master the concepts required to learn to use the abacus. For those children who lack adequate finger dexterity and who cannot overcome this stumbling block to

success with the Cranmer Abacus, that device may be the least effective tool for arithmetic computation.

Recommendations for Further Research

1. A long-term replication of this study should be conducted. It should be carried out over a period of several years. During that time, all four arithmetic processes should be studied.
2. A study to determine the best age at which to begin teaching the use of the Cranmer Abacus should be carried out.
3. A study should be conducted to determine what effect varying degrees of manipulative skills have on facility in using the abacus.

APPENDIX A

DESCRIPTION OF THE DESIGN AND OPERATION OF THE CRANMER ABACUS

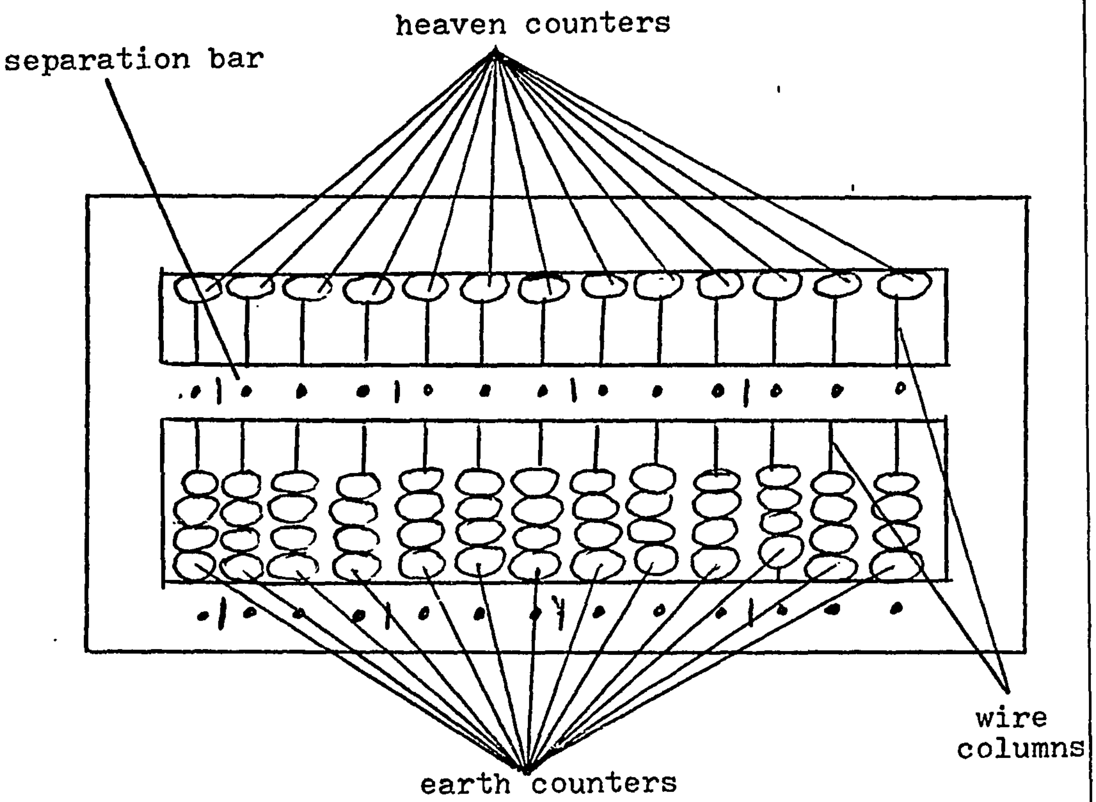
The following description, with some changes, was first set forth by Jacquat (n. d.). The Cranmer Abacus is rectangular in shape measuring 3 x 6 inches and is 3/8 of an inch deep. The frame is plastic with a foam and felt backing. Attached to the frame are thirteen vertical wire rods or columns, each holding 5 counters or beads. Running the length of the frame is a horizontal bar which cuts across all thirteen columns and separates the top counter on each column from the remaining four. This bar is named the separation bar. On this bar and also along the bottom of the frame, there are single dots indicating the position of the columns. Also, from right to left, after every third column, there is a line called a unit mark which marks the comma locations, and, in some cases, the decimal locations.

The abacus should generally be placed on a table or desk in front of the operator and left resting on that surface during its use. The single counters above the separation bar are called heaven counters, and each of them equals five. The four counters below the separation bar on each column are called earth counters, and each of them is equal to one. When a counter is moved close to

the bar, it takes on its assigned value (i.e. heaven = 5 each, earth = 1 each). When the counter is moved away from the bar, it has been cleared and has no value. When a counter is moved toward the bar, thus giving it value, the counter has been set. "Set one left" or "clear one left" means to set or clear one bead on the column immediately to the left of the column upon which the operation is taking place. The column farthest right on the abacus is the units column. The next column to the left is the tens column. The hundreds column is next. There are thirteen such columns with the last being the trillions column (see Illustration 1 for a detailed diagram).

Illustration 1

THE CRANMER ABACUS



APPENDIX B

KANSAS STATE SCHOOL FOR THE VISUALLY HANDICAPPED
OVER A CENTURY OF SERVICE. ESTABLISHED 1867.

1100 STATE AVENUE
KANSAS CITY, KANSAS 66102
TELEPHONE (913) 281-3308

December 6, 1973

Mr. Gaylen Kapperman
2908 State Farm Road, Apt. #3
Evans, Colorado 80620

Dear Mr. Kapperman:

In reply to your letter of December 3, I can assure you that the braille students at the Kansas State School for the Visually Handicapped are taught to compute mentally and also by use of the braillewriter.

Sincerely,

Burton J. Lewis
Burton J. Lewis
Superintendent

BJL:cr

APPENDIX C

Test A

1. 2 + 5 = 7
2. 2 + 6 + 1 = 9
3. 70 + 20 = 90
4. 30 + 20 + 20 = 70
5. 16 + 83 = 99
6. 52 + 22 + 15 = 89
7. 9 + 4 + 7 + 6 = 26
8. 4 + 3 + 2 + 8 + 7 = 24
9. 5 + 6 + 8 + 9 + 6 + 4 = 38
10. 57 + 26 = 83
11. 58 + 22 + 14 = 94
12. 29 + 18 + 46 = 93
13. 75 + 69 + 58 = 202
14. 45 + 78 + 57 + 32 = 212
15. 59 + 74 + 67 + 22 + 85 = 307
16. 789 + 698 = 1489
17. 273 + 439 + 187 = 899
18. 553 + 382 + 778 + 866 = 2579
19. 659 + 398 + 845 + 506 + 264 = 2672
20. 6423 + 5906 + 4381 = 16710
21. 7548 + 5825 + 4863 + 9877 = 28113
22. 8727 + 4457 + 6912 + 9033 + 5865 = 34994
23. 5914 + 7243 + 4639 + 8707 + 6151 + 3617 = 36271

Test B

1. 4 + 5 = 9
2. 3 + 1 + 3 = 7
3. 30 + 60 = 90
4. 10 + 40 + 30 = 80
5. 42 + 36 = 78
6. 21 + 34 + 43 = 98
7. 3 + 8 + 9 + 5 = 25
8. 7 + 2 + 1 + 5 + 6 = 21
9. 7 + 9 + 2 + 6 + 8 + 7 = 39
10. 26 + 58 = 84
11. 35 + 46 + 17 = 98
12. 35 + 19 + 38 = 92
13. 79 + 56 + 68 = 203
14. 37 + 72 + 58 + 46 = 213
15. 76 + 82 + 28 + 54 + 65 = 305
16. 679 + 789 = 1468
17. 176 + 245 + 468 = 889
18. 891 + 373 + 656 + 748 = 2668
19. 706 + 354 + 279 + 647 + 598 = 2584
20. 7406 + 4832 + 3692 = 15930
21. 8632 + 7746 + 4975 + 3569 = 24922
22. 5515 + 7067 + 8923 + 3457 + 6736 = 31698
23. 4133 + 8337 + 6944 + 3302 + 7117 + 5759 = 35592

Test C

1. 6 + 2 = 8
2. 4 + 3 + 1 = 8
3. 40 + 30 = 70
4. 20 + 40 + 30 = 90
5. 57 + 31 = 88
6. 43 + 11 + 33 = 87
7. 8 + 7 + 9 + 3 = 27
8. 5 + 2 + 6 + 3 + 7 = 23
9. 4 + 3 + 9 + 8 + 5 + 8 = 37
10. 47 + 28 = 75
11. 24 + 37 + 28 = 89
12. 39 + 27 + 25 = 91
13. 58 + 67 + 79 = 204
14. 52 + 48 + 35 + 79 = 214
15. 82 + 27 + 55 + 68 + 74 = 306
16. 798 + 688 = 1486
17. 348 + 167 + 474 = 989
18. 747 + 296 + 863 + 571 = 2477
19. 345 + 597 + 604 + 259 + 778 = 2583
20. 5852 + 7381 + 3607 = 16840
21. 5973 + 4826 + 6548 + 8764 = 26111
22. 6932 + 7465 + 9426 + 4813 + 5047 = 33683
23. 7328 + 4953 + 5601 + 4229 + 8143 + 2917 = 33171

APPENDIX D

RAW DATA

Subject	Age	IQ	Accuracy Aba	Accuracy Brl	Accuracy MtC	Speed Aba	Speed Brl	Speed MtC	Efficiency Aba	Efficiency Brl	Efficiency MtC
1	233	101	11	12	18	37	34	20	.2973	.3529	.9000
2	182	118	11	15	16	45	60	47	.2444	.2500	.3404
3	147	108	11	14	13	30	35	16	.3667	.1400	.8125
4	135	113	19	22	14	46	48	25	.4130	.4583	.5600
5	235	57	15	14	16	55	85	66	.2727	.1647	.2424
6	232	86	4	20	20	36	73	29	.1111	.2740	.6897
7	200	100	15	16	14	20	24	11	.7500	.6667	1.2727
8	235	109	17	22	20	29	34	20	.5862	.6471	1.0000
9	181	111	18	17	14	48	50	51	.3750	.3400	.2745
10	156	120	19	23	17	27	29	31	.7037	.7931	.5484
11	171	101	13	23	19	33	36	17	.3939	.6389	1.1176
12	152	112	16	20	18	30	36	20	.5333	.5556	.9000
13	219	82	18	19	18	37	40	75	.4865	.4750	.2400
14	177	82	19	22	11	35	26	30	.5429	.8462	.3667
15	146	106	9	9	11	66	54	79	.1364	.1667	.1392
16	213	104	20	21	21	21	17	16	.9524	1.2353	1.3125

Age--Age in months

IQ --Wechsler Intelligence Scale for Children (Verbal Scale)

Aba--Cranmer Abacus

Brl--Braillewriter

MtC--Mental Calculation

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